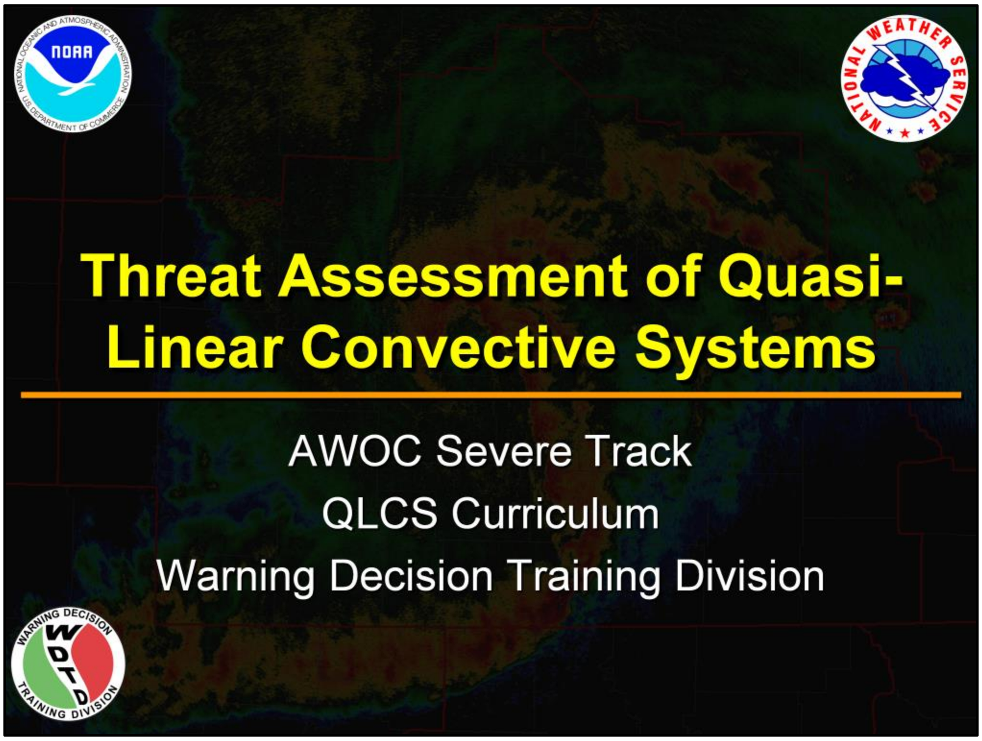

Welcome to AWOC Severe IC 2 Lesson 3 , Threat Assessment of Quasi-Linear Convective Systems (or QLCS). My name is Brad Grant, Team Leader of the Warning Decision Training Branch in Norman. I will be narrating this lesson along with other meteorologists listed on this slide, who have been the primary content collaborators for this lesson. Duration of this lesson is about 27 minutes.

Welcome to AWOC Severe Storm-Based Warning Primer Less...

Tabs - 4 Tabs (Including Introduction)

Last Modified: May 11, 2015 at 11:45 AM

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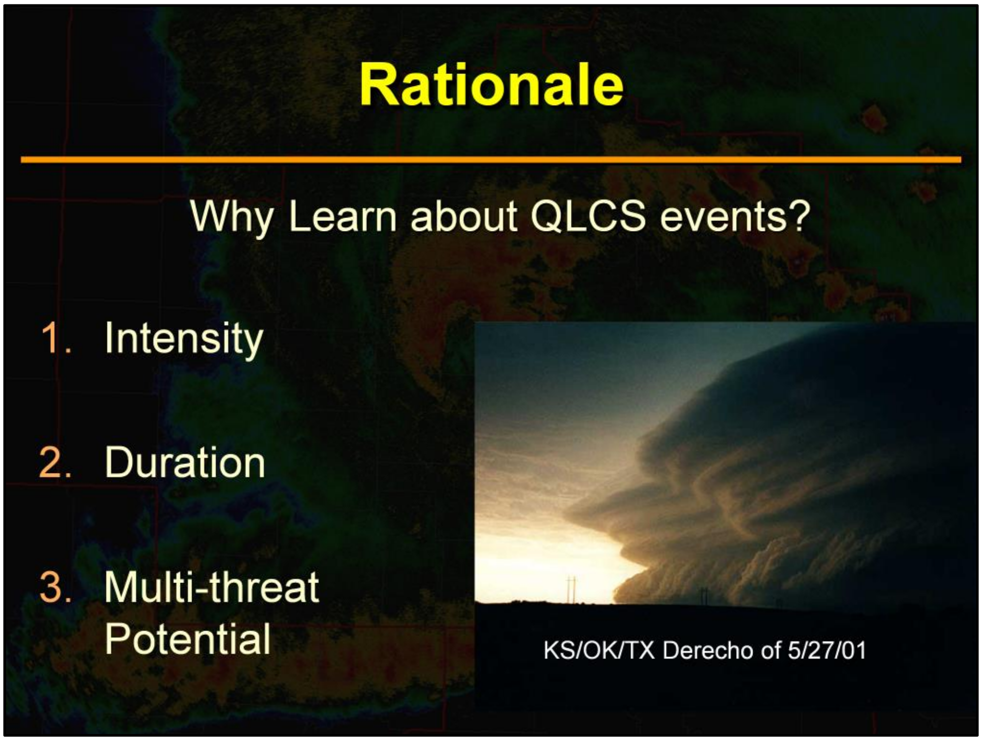
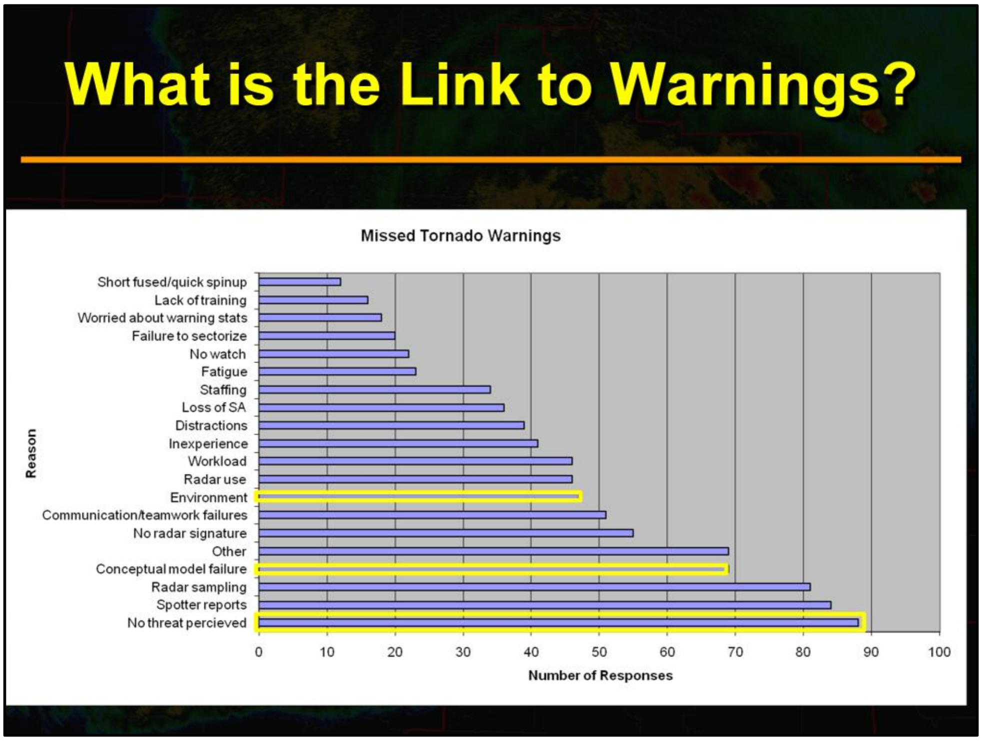


So, why do we need to learn about QLCS Events?

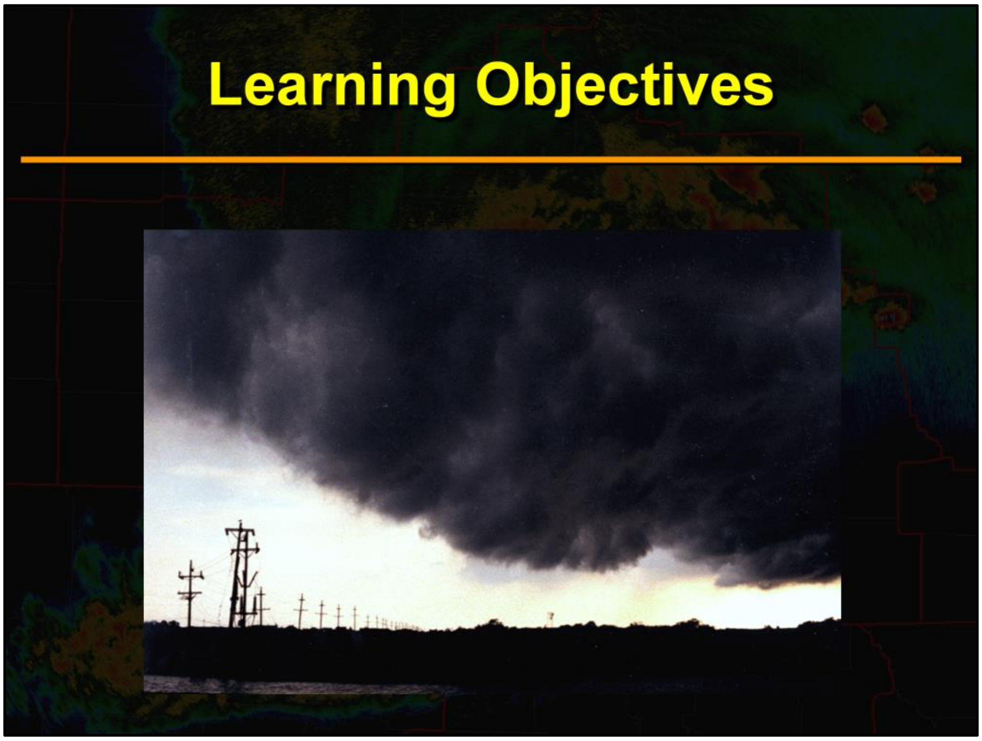
The answer is that many long-lived multicell convective systems have a propensity to take lives and damage property with high winds, hail, and tornadoes. Damage often occurs over a broad swath encompassing multiple county warning areas. Danger to public in these situation is obvious and often more extreme, impact-wise, than a single tornado storm. Challenges for a warning forecaster on the threat assessment level include:

- Recognition of the intensity of these type of events
- Determination of duration and movement, and
- Determination of all the threats associated with these type of events.

In this lesson, which is a companion to the storm interrogation module in IC Severe 3 on recognition and detection of QLCS storm-scale features, we are going to treat many of these challenges associated with forecasting QLCS events.

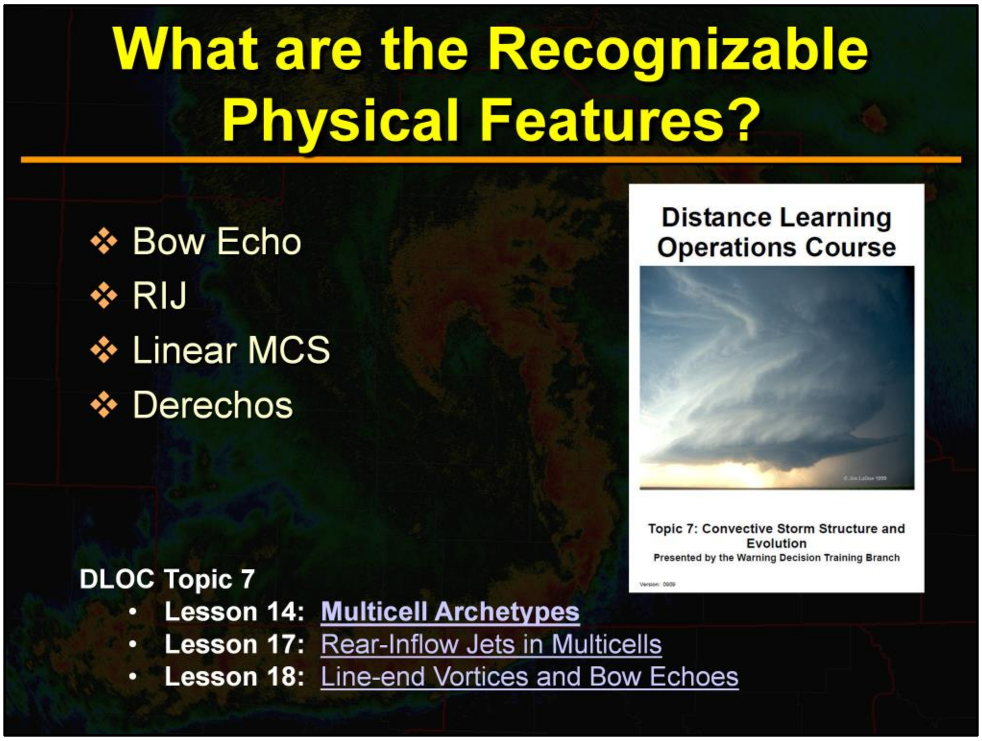


When individual forecasters analyze the root cause for missed tornado events, like this chart from AWOC Core (2004-05), one of the reasons frequently cited for missing events is the lack of a perceived threat. This can be a result of a number of things, including aspects of environmental analysis , or a failure of a conceptual model. In the case of QLCS events, the ability to use a correct conceptual model to recognize threats typically associated with the events is a big part of successful threat assessment.

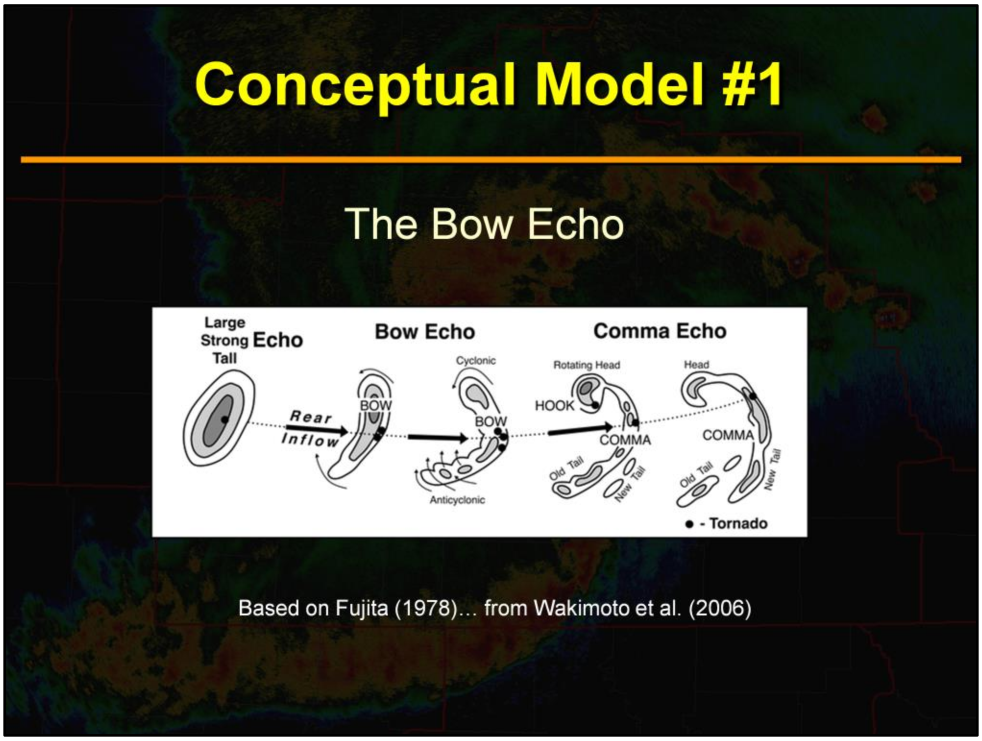


For this lesson on threat assessment of QLCS events, we have identified 6 learning objectives, as listed in the speaker notes:

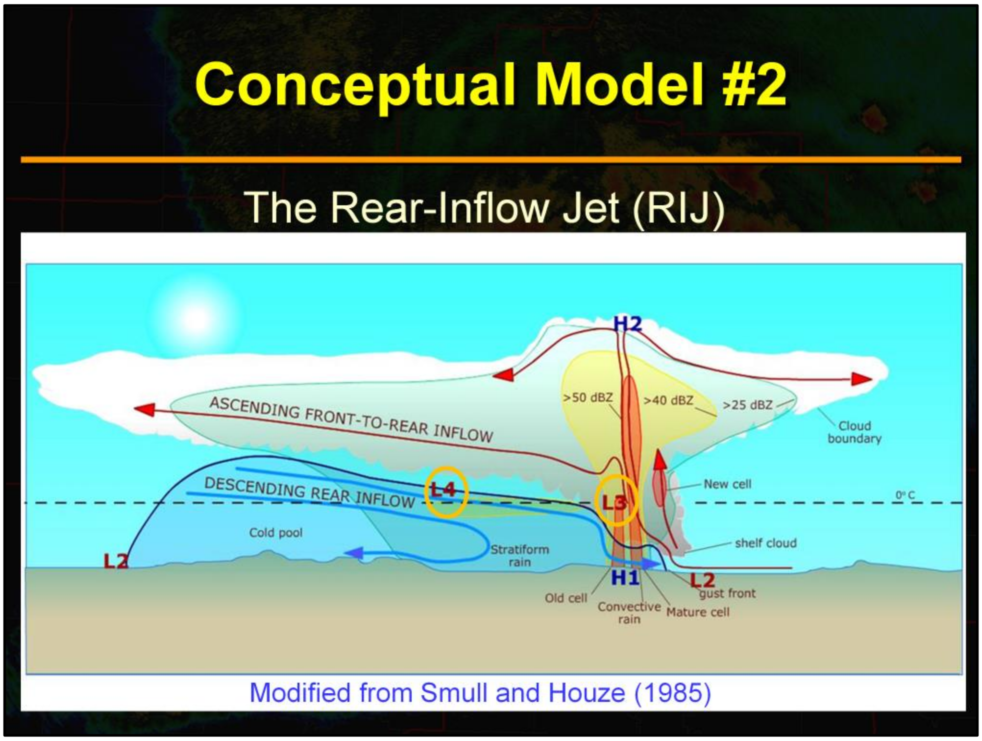
1) Identify some of the key features found in conceptual models of QLCS events.
2) Identify the types of QLCS events that produce the most intense impacts.
3) Identify parameters for evaluating the severity of QLCS events.
4) Identify discrimination capabilities of parameters used in forecasting QLCS events.
5) Identify patterns/parameters that affect longevity of a QLCS.
6) Determine motion of a QLCS (both forward propagating and backward).



An understanding of the primary features and associated physical processes of some of the well-accepted conceptual models of long-lived multicell convective systems is essential to evaluating QLCS environmental threats. Most of the physical features listed here have been identified in various conceptual models of QLCSs. Well-known radar features like the bow echo and the RIJ (Rear Inflow Jet) are described in the DLOC Topic 7 Lessons listed here. If you haven't taken these modules in a while, it would be worth your time as these features are discussed in more detail than they will be in this lesson.



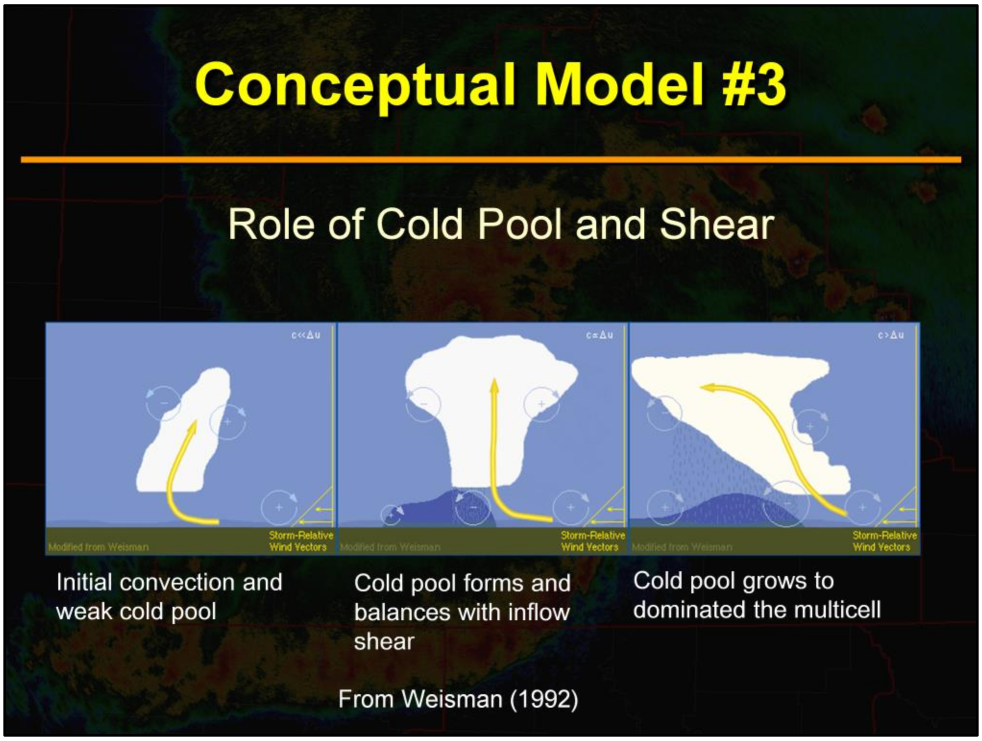
Conceptual models of quasi-linear convective systems span several years. One of the earliest models was Fujita (1978), who defined the evolutionary stages of convective development from conventional radar signatures as in the image shown on this slide. There was an initial large, strong echo which developed into a bow echo with cyclonic and anticyclonic rotation , and then into a comma shaped echo. The bulging portion of the line of echoes was termed a “bow echo” , which he said was produced by thunderstorm downburst winds. Fujita also noted cyclonic and anticyclonic circulations at the ends of the bowing segments. Later bow echo researchers such as Weisman (1993) referred to these counter rotating circulations as “bookend vortices.” This early conceptual model fit well with other models on squall line type bow echoes and presented that the bow echo bulge was associated with a strong rear-inflow jet. There was also important work conducted on discriminating the location of tornadoes with bow echoes (black dots in this figure).



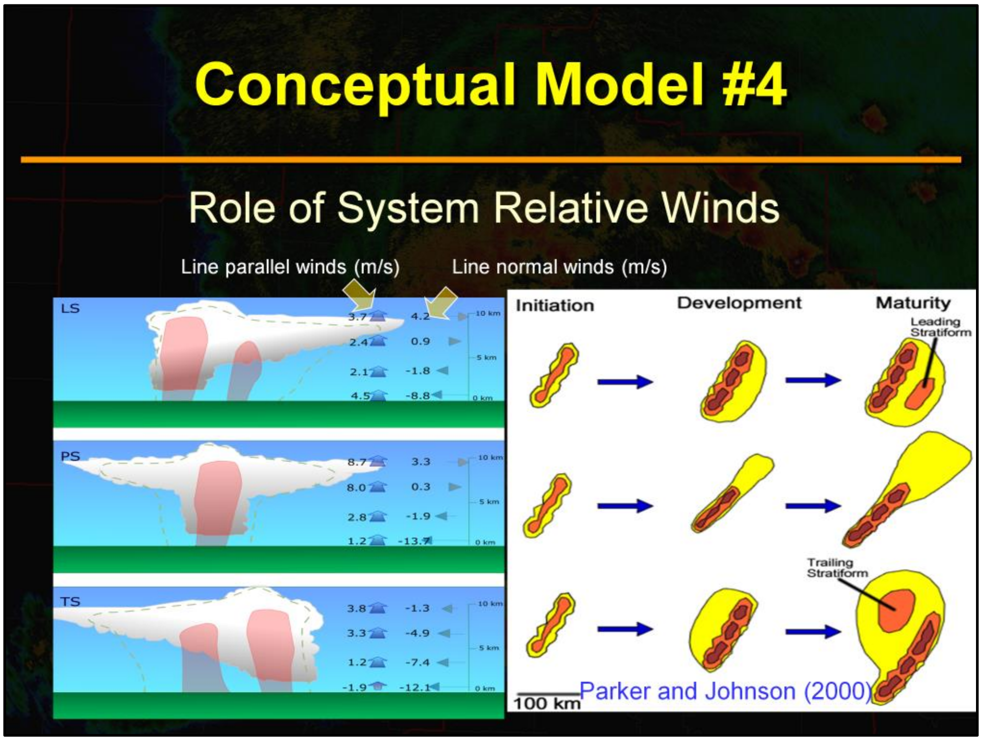
Smull and Houze, as well as other researchers, examined a number of squall lines using radar data and concluded that the bulge and associated concavity seen in Fujita's bow echo was directly related to the rear-inflow jet. How did the RIJ form the bow echo? By doing two things: 1) advecting part of the squall line forward and 2) entraining dry air into the rear flank which then erodes the back side of the echo through evaporation of hydrometeors. They developed a complex conceptual model of a mature squall line within a Mesoscale Convective System (or MCS) that included a large anvil and a cold pool that modulated the pressure field from the surface to upper levels.

The development of the RIJ was attributed to midlevel, mesoscale areas of low pressure (labeled L3 & L4). The RIJ transported strong buoyant ambient air to the anvil. The mesolow "L3", formed immediately behind the leading line convection, was a hydrostatically-induced negative pressure perturbation that develops under up- shear tilted warm convective updrafts and above the attendant cooled downdrafts. Midlevel mesolow "L4" forms in the stratiform region in between the warm buoyant air which gets pulled rearward past the cool, dry descending air flow. Note that there are can be significant differences in the evolution of multicell systems based on the strength of the cold pool, ambient shear, and attendant RIJ. But one thing appeared to be clear, the RIJ could push descending air all the way to the front of the leading line in the most extreme, long lasting situations.

As more details emerged from examining the thermodynamic structure within a mature mesoscale convective system containing a squall line, the focus in research switched to numerical simulations and the role of the cold pool and ambient shear.



Modeling studies by Weisman suggested that shear in the lowest 2.5 km and the strength of the cold pool controlled the orientation of the rear-inflow jet . A typical transition shows ideally what takes from an initial surface based convective element to a multicell. Discrete multicellular convection initiates from forcing, and slowly generates a cold pool that builds in strength over time. Multicell forcing may be dominated by either external forcing or updraft induced dynamic pressure gradients. Eventually the cold pool may take control of the multicell including both the initial forcing and its embedded updraft forcing. How long it takes for the cold pool to dominate depends on how strong the cold pool becomes compared to the vertical wind shear and the strength and orientation of the initial forcing.

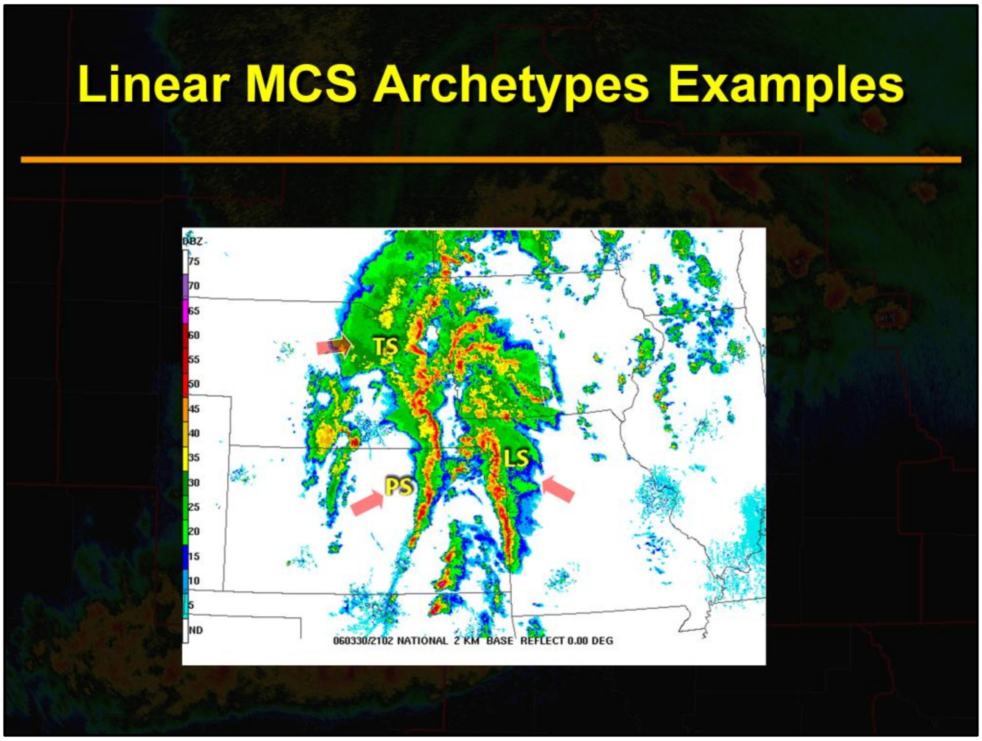


One of the most recent conceptual models of MCS and how they develop are from Parker and Johnson (2000).

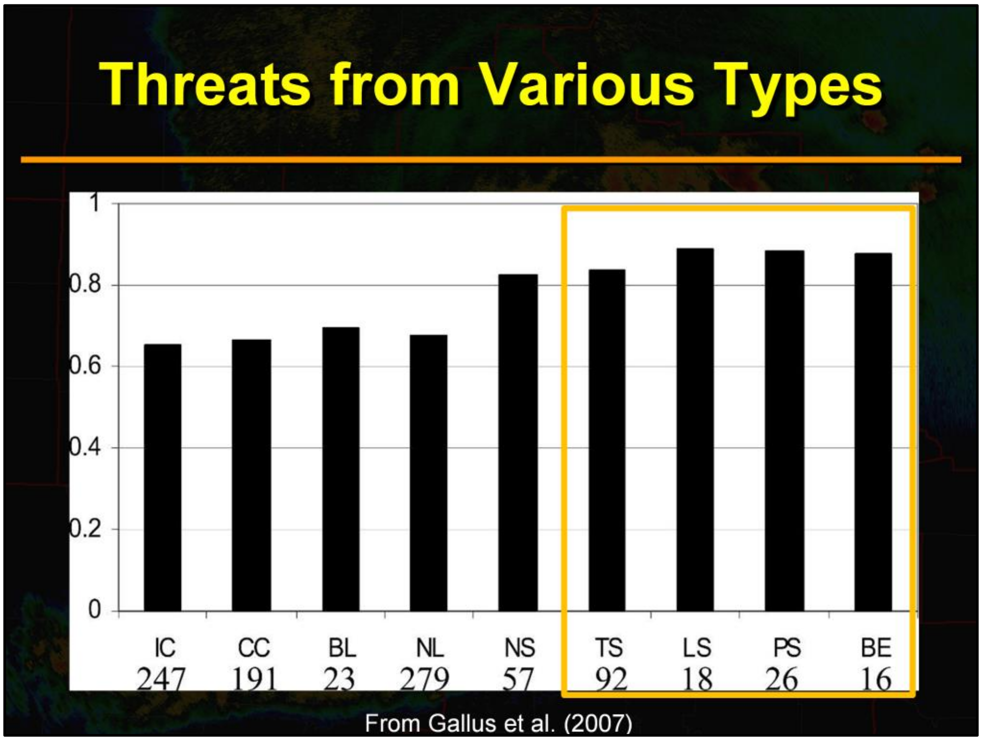
Although MCSs develop a number of ways, typical mature systems contain convective and stratiform precipitation regions. The eventual MCS type is determined to a large extent by the environmental conditions in which it develops and the strength of the system cold pool. Parker and Johnson studied numerous MCSs and determined the distribution of hydrometeors and stratiform precipitation shapes were largely a result of mean storm-relative winds. **The speed and direction of the environmental mid- and upper-level winds relative to system motion affect the resulting evolution of the MCS.**

According to their studies, Parker and Johnson (2000) found MCS squall lines evolve into three major archetypes (shown in their modified figure from top to bottom): **1) Leading Stratiform, 2) Parallel Stratiform, and 3) Trailing Stratiform**. The main distinction arose from storm-relative flow fields. For more details on these three multicell archetypes, please refer back to Lesson 12 of DLOC Topic 7.

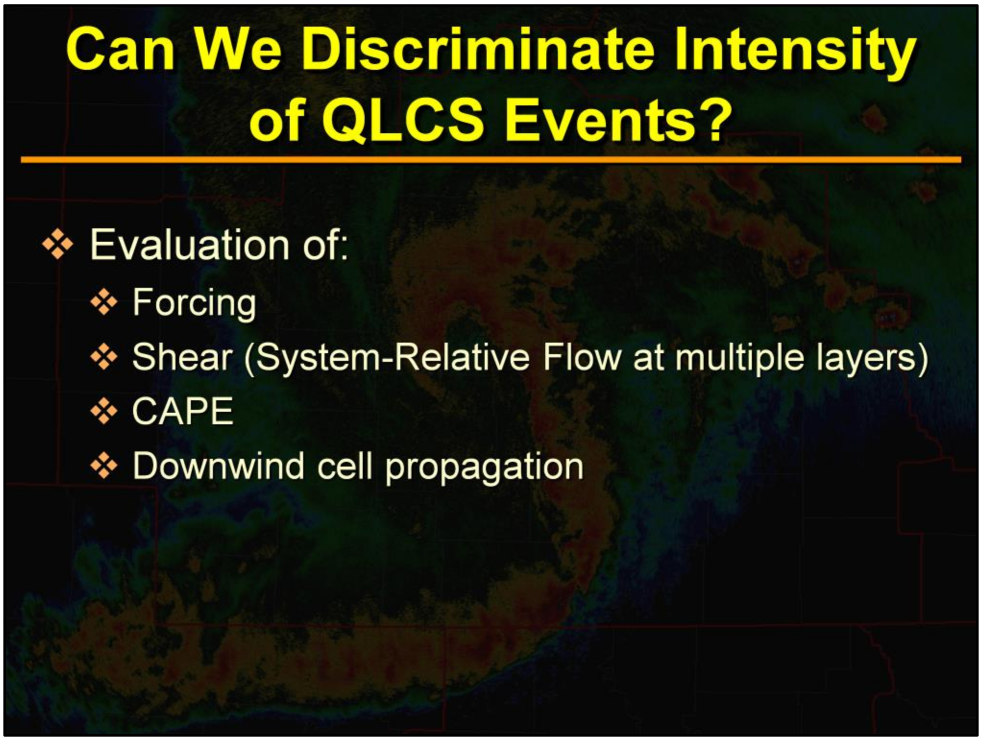
More recent conceptual models of QLCS events, especially on the storm scale, will be presented in parts of AWOC IC Severe 3: Storm Interrogations.



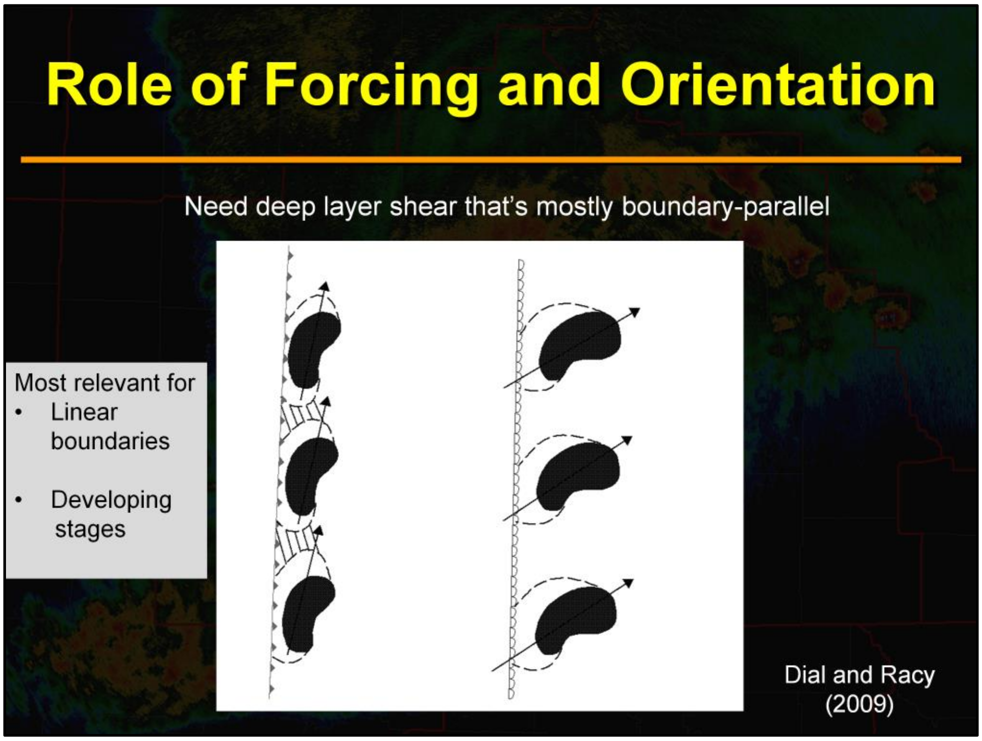
This figure shows an example of all three archetypes occurring simultaneously ahead of an ejecting strong upper-level shortwave trough. Each MCS formed from a different boundary. The TS formed on a stationary front north of the surface low, the PS formed on a dryline, and the LS formed on what may have been a residual outflow boundary with the cooler air to the east (French and Parker, 2006).



While we can to some degree distinguish (after the fact) environments and radar morphologies of resulting QLCS events, an important point is that ALL types can produce severe weather . This graph from a study by Gallus et al. shows the percentage of storms with at least one severe report (not including flooding), organized by morphology. The morphology TS, LS, and PS are similar to Parker and Johnson’s notation. BE is for Bow Echoes. The numbers of events of each type are shown beneath the morphology codes.

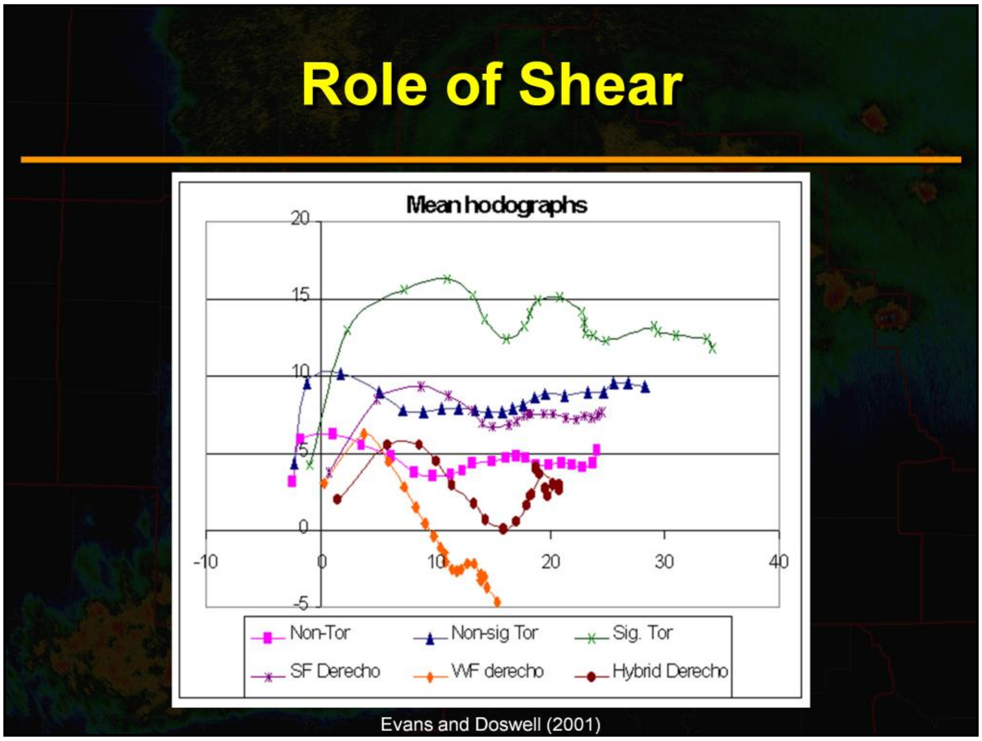


To identify the types of QLCSs that produce the most intense impacts, you must evaluate forcing, shear (at low, mid- and upper-levels), CAPE, especially in the region supporting updraft parcels, and especially, the potential for downwind cell propagation.



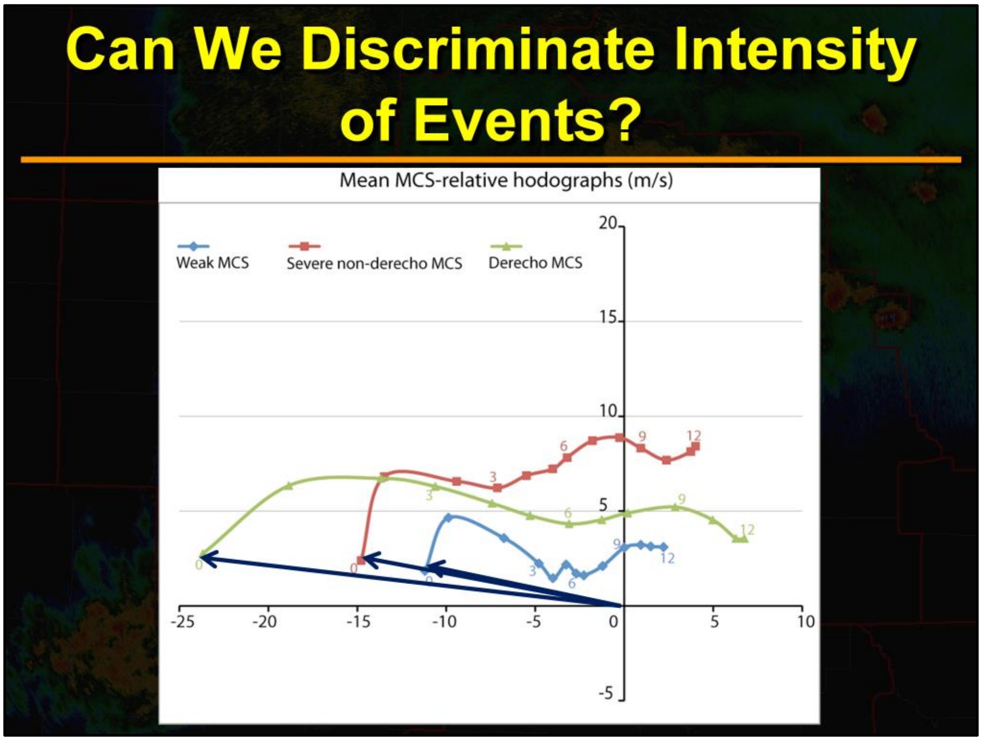
Large multicells are more apt to exhibit a linear nature to them reflecting the elongated lifting that commonly occurs along external forcing mechanisms (e.g., fronts), and internally generated cold pool boundaries. Fronts offer a linear nature to forcing, however multicells may not merge into a long line if the forcing is weak. If the deep layer shear is largely boundary-parallel (such as the left-most evolutions) individual cold pools may more easily merge, reinforce the front, and enhance upscale growth into a long line.

In terms of forcing, the next image is a similar depiction showing the initiation of storms in two different flow regimes relative to a boundary. The dark arrows represent the mean cloud-layer wind and shear vector orientations, the shading represents precipitation regions, the dotted lines are convective outflow and the hatched areas indicate where new development is likely as convective outflows merge (from Dial and Racy, 2009). Once again, the most intense QLCSs likely develop from the orientation shown on the left. Note that both of these results are most relevant in situations along well defined, linear boundaries and most appropriate during the developing stages of the QLCS.

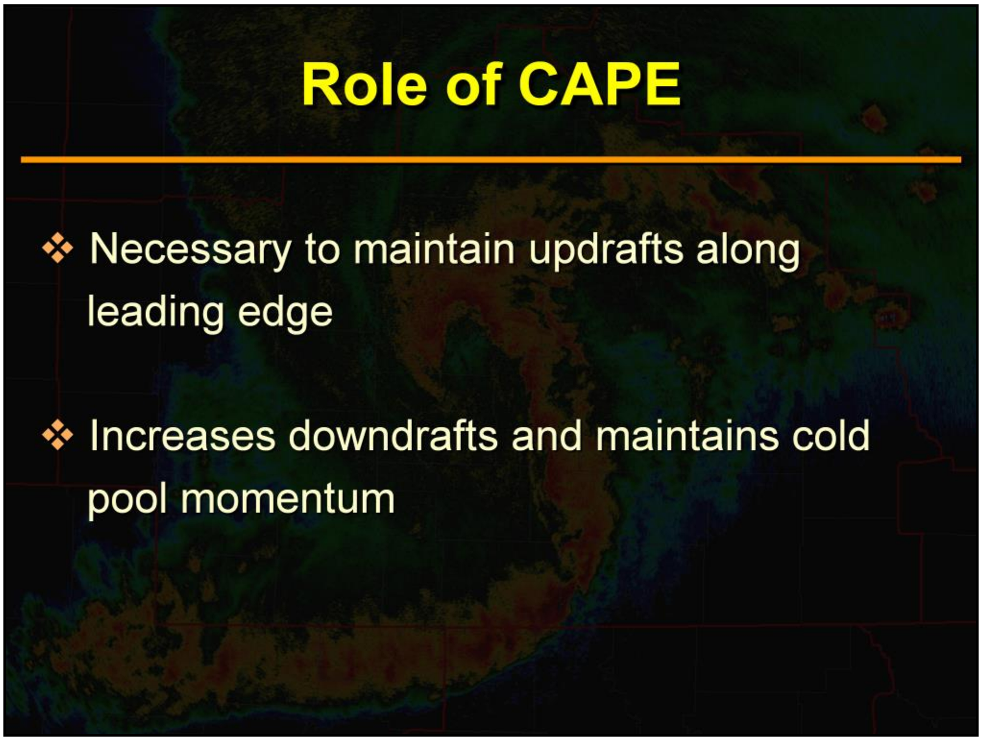


This plot of composite hodographs from Evans and Doswell (2001) illustrates differences in mean wind profiles associated with derechos and discrete supercells . The hodographs were created from proximity soundings near 65 derechos, stratified by synoptic-scale forcing strength, and 100 supercells divided into: non-tornadic, F0-F1 tornadoes (Non-sig Tor class), and those producing F2 or greater tornadoes (that's your Sig Tor class). The differences in these mean hodographs indicate that shear plays a very important role in helping determine the organization potential and ensuing severe threats.

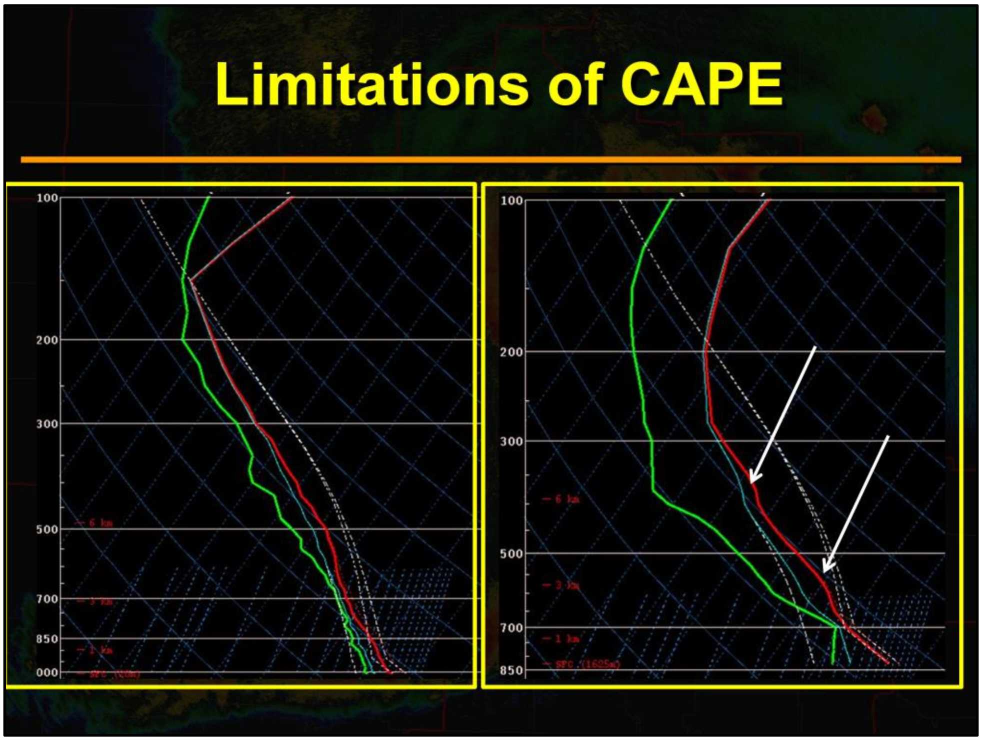
The SF derechos (dark maroon colored line) occur in stronger flow and shear than the other derecho categories. The WF Derechos (shown on the orange line) commonly occur in weaker shear environments. In addition, the mean WF derecho hodographs indicate weaker and more uniform northwesterly flow at mid and upper levels. In comparison, the significant tornadic supercells (green line) have much longer hodographs and more substantial low and deep layer shear. However, it important to note the similarities between the SF derecho and tornadic supercells mean wind profiles. In fact, the SF derecho average falls well within the range of shear magnitudes and hodograph structure associated with discrete supercells producing F0-F1 tornadoes. Shear, though a necessary ingredient, will not provide a complete picture regarding the impending mode of expected thunderstorms. It is very important to also consider the nature of initiation and storm motion/speed relative to the initiating boundary when dealing with strongly forced synoptic events.



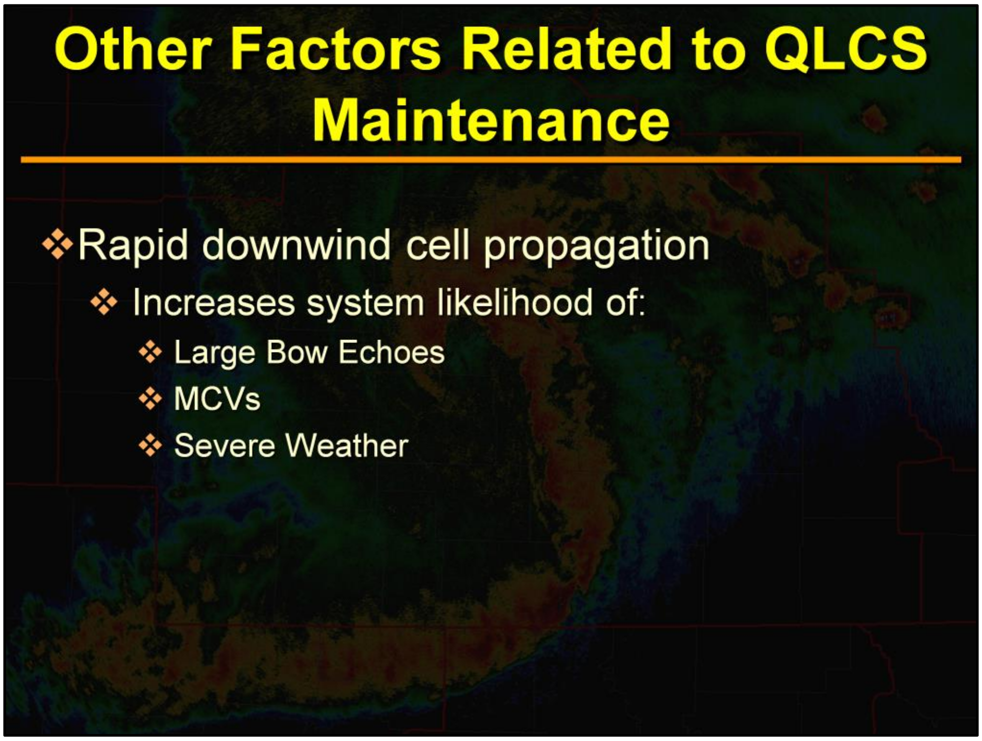
To address the question of distinguishing run-of-the-mill MCSs from high-end events, the figure shown is a graphic of mean MCS-relative hodographs from a proximity sounding data set of 55 weak MCSs (shown in blue), 78 severe but non-derecho MCSs (show in red), and 51 derecho MCSs (shown in light green) that were taken in the downshear environment during the developing stages of the systems. This analysis is based on the data set described in Cohen et al. (2007) in W&F. The mean hodograph clearly shows that shear becomes more stretched and straight-line along the x-axis (MCS-motion) as you go from the weak MCSs to the derecho MCSs (the colored numbers along the hodographs are kilometers Above Ground Level (AGL)). You can also see the huge increase in low-level storm-relative inflow for the derecho MCSs.



The role of convective instability is multifaceted. Not only is sufficient CAPE necessary to maintain intense updrafts along the leading edge of the cold pool, but the larger the CAPE the more intense the updrafts and resultant supply of moisture and energy to the overall MCS. This in turn increases the subsequent downdrafts and strengthens or at least maintains the cold pool momentum. If CAPE weakens or the outflow surges into an environment of little or no CAPE and/or significant convective inhibition, then the convective system would quickly lose its energy source and diminish- sometimes quite quickly.



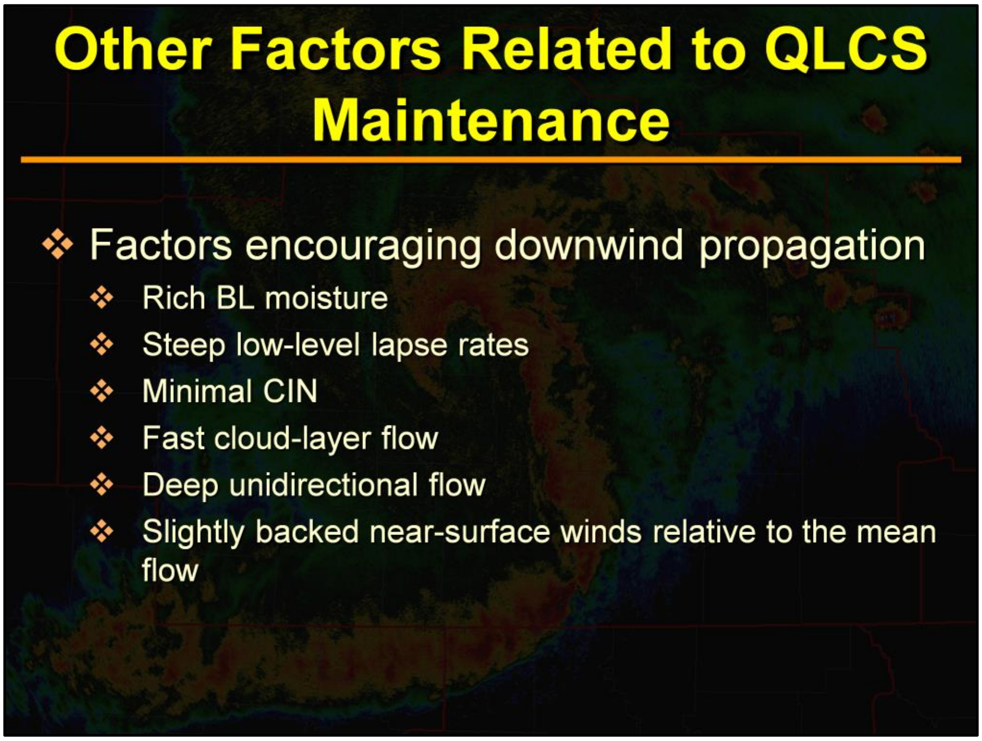
There are a couple of caveats of using CAPE. CAPE alone can be misleading, and is most relevant when used in combination with environmental lapse rates or lifted-indices. For instance, one can derive equal amounts of CAPE from a deep, moist sounding (shown on the left) and a more typical mid-latitude Spring-like sounding shown on the right. However, the steep lapse rates in the second sounding would be expected to support greater vertical motion within the ensuing updraft and stronger/colder downdrafts. In addition CAPE is very dependent on the lifted parcel choice. Craven et al. 2002 found that lifting a 100-mb mixed parcel was most representative of cloud heights near peak heating.



To anticipate high-end QLCS events, it is important to identify environments that are conducive to *rapid, downwind cell propagation* near an existing thunderstorm or a group of storms. "Downwind cell propagation" is simply the development of new thunderstorms on the downwind side of existing convection.

Environments that foster rapid downwind propagation are those that allow incipient convective systems to continuously redevelop --- and potentially grow upscale. Such systems are more likely to produce large-scale bow echoes, MCVs, and severe weather.

Although many factors ultimately govern the rate and location of new cell development relative to existing storms, downwind propagation is especially encouraged by the presence of the following:



(1) Rich boundary layer moisture --- Moisture-rich air fosters new storm development by lowering the LCL and enhancing precipitation drag

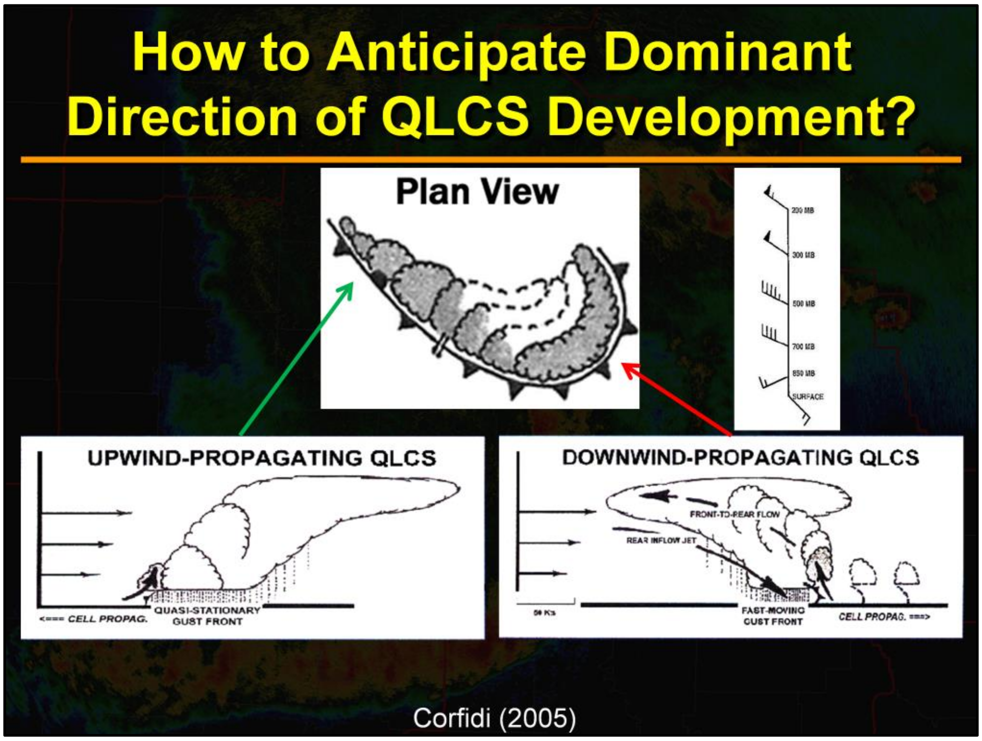
(2) Steep low-level lapse rates --- Steep lapse rates enhance both CAPE and downward momentum transfer

(3) Minimal Convective Inhibition or CIN --- The potential for storm initiation is maximized when CIN is low

(4) Fast cloud-layer flow --- Fast flow increases gust front speed by strengthening storm outflow; fast flow also fosters the development of embedded supercells and their associated severe threats

(5) Deeply *unidirectional* flow --- Unidirectional flow encourages elongation of the system cold pool in a preferred direction, thereby enhancing storm-relative inflow in that direction

(6) Slightly-backed near-surface winds relative to the mean flow --- Backed low-level winds enhance storm-relative inflow and the rate of downwind cell development

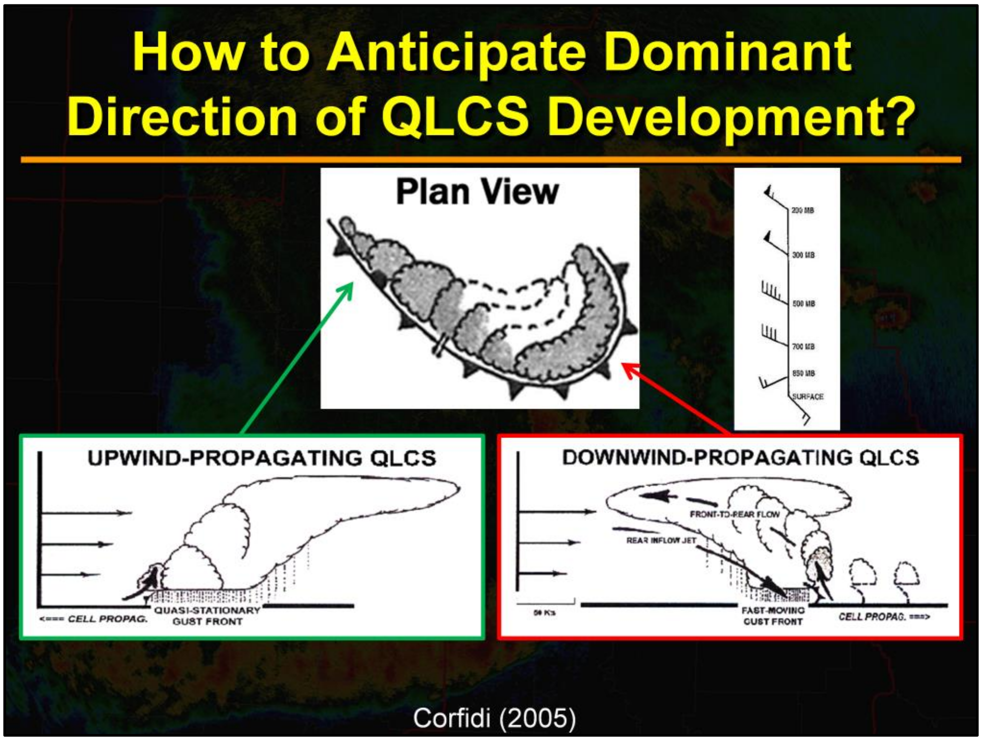


The previous slide noted that unidirectional flow encourages elongation of convective system cold pools along the direction of the mean flow.

As a cold pool elongates, a portion of its associated gust front necessarily becomes oriented perpendicular to the flow, while the other part comes to lie parallel to it. This process is shown schematically for unidirectional northwest flow in the plan view at the top of the slide.

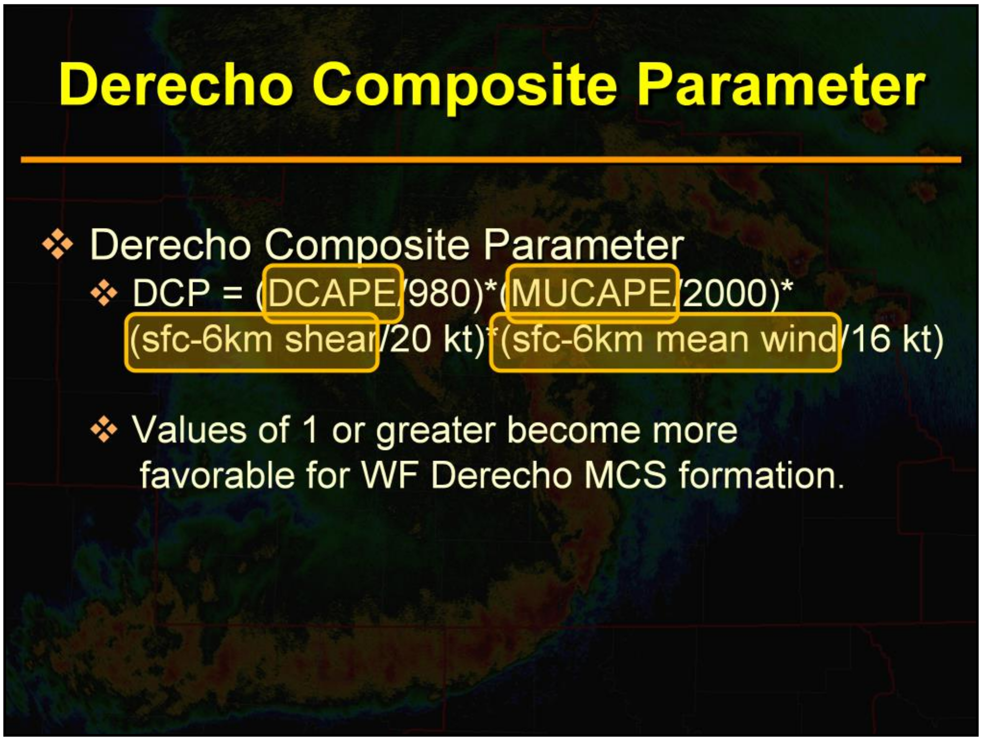
Recurring production of storm outflow along the part of a gust front oriented perpendicular to the mean wind --- and downward momentum transfer --- cause that part of the gust front to move steadily downwind with time. This is shown on the right side of the plan view in the slide. In contrast, the flow-parallel portion of the boundary moves very slowly or not at all, as shown on left side of the plan view.

The orientation of the gust front relative to the mean flow is important in determining the direction of cell propagation and, therefore, the type of MCS that will be most favored along it.



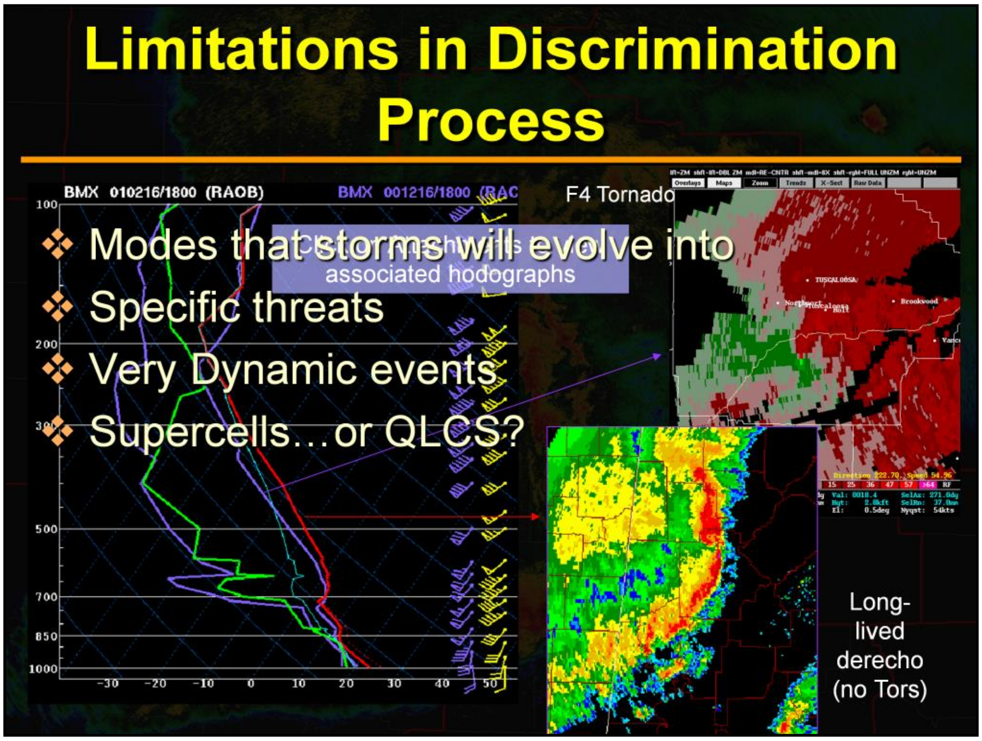
If low-level convergence and the thermodynamic environment are favorable for new cell development along the flow-parallel portion of the gust front, a **back-building or regenerative MCS** is likely to develop, as shown in the lower left inset of the slide. Such convective systems are best known for their ability to produce excessive rainfall as storms "train" or move repeatedly along the stationary boundary. But if sufficient cloud-layer shear is present, embedded supercells and LEWPs (line echo wave patterns) may yield damaging winds and tornadoes, especially when the moisture content is great.

If convergence and instability are favorable for storm development along the flow-perpendicular part of the gust front, a **downwind-developing or "forward-propagating" MCS** is likely to form, as seen in the lower right inset. Because new storm development occurs in the direction of the mean wind, the convective system can move faster than the mean flow. Such systems may evolve into a bow echo or derecho-producing MCS if the rate of forward propagation is great --- and this condition persists.



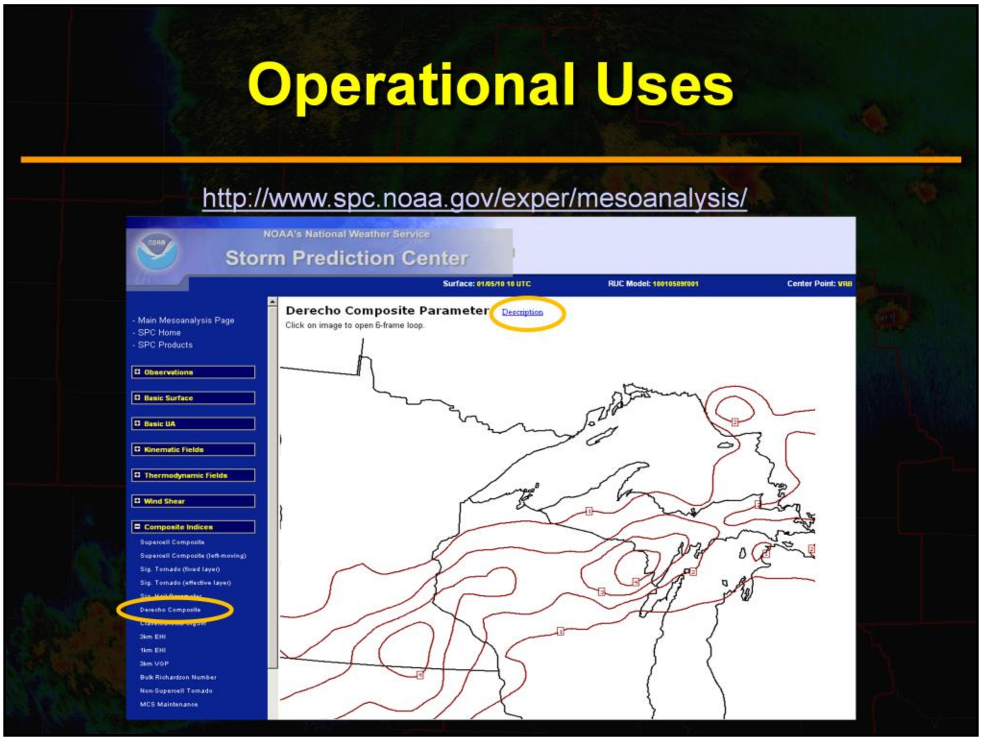
As forecasters attempt to differentiate between typical warm season, non-severe MCS development versus a forward-propagating/accelerating-Derecho MCS, SPC developed a parameter that is based on 113 Derecho soundings from ED01. This parameter examines four primary mechanisms discussed previously for MCS forward propagation development: 1) DCAPE, used as a proxy for cold pool strength and/or strong downdraft production, 2) MUCAPE- was used as a proxy for the ability to sustain strong storms along the leading edge of the gust front, 3) Surface to 6 km shear, used to account for potential of organization , and 4) Surface to 6 km mean wind to account for favorable ambient flow to elongate the cold pool in a favored downshear direction. Similar to other composite indices developed at the SPC, a value of 1 or greater becomes favorable for a weak forcing Derecho development. Each of these parameters was 'normalized' by mean values developed from the ED01 proximity sounding dataset.

DCP = (DCAPE/980)*(MUCAPE/2000)*(sfc-6 shear/20 kt)*(sfc-6 km mean wind/16 kt)



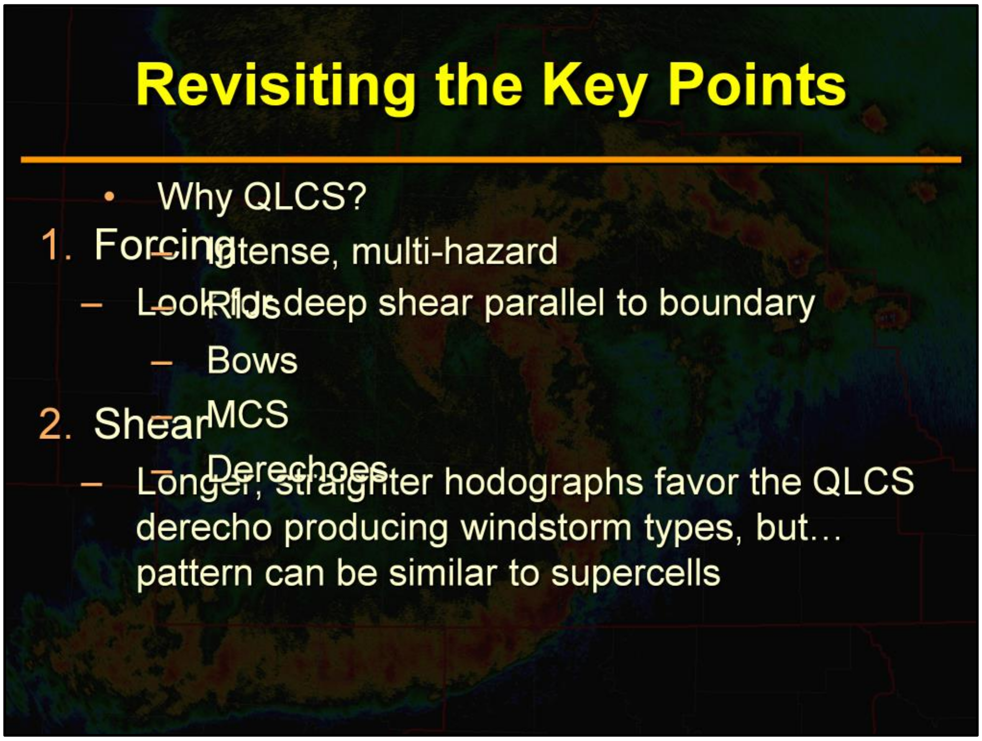
As mentioned in earlier slides, there are many limitations to discriminating what mode storms will develop and evolve into, and what specific severe threats will ensue. This is especially true when dealing with very dynamic events associated with strong large scale ascent and pronounced low and deep layer shear- which are typical from Fall into late Spring. Despite very favorable wind profiles for discrete tornadic supercells, limited thermodynamic support and/or the nature of initiation may force storms to evolve in the form of a fast moving QLCS. For instance in cases where capping remains strong in the warm sector, development may remain tied to a fast moving surface boundary. Also, many times the mean storm motion vector is not sufficient in magnitude and/or direction to move updrafts away from the initiating feature.

The images shown here are an example of how similar environments can produce distinctly different thunderstorm modes and severe weather. These are two proximity soundings: 1) near the F4 tornado which struck Tuscaloosa, AL on Dec. 16th, 2000 (in purple), and 2) near the long-lived derecho MCS which produced widespread wind damage and one fatality (but no tornadoes) as it swept across central AL on Feb 16th, 2001 (red/green and yellow wind barbs).



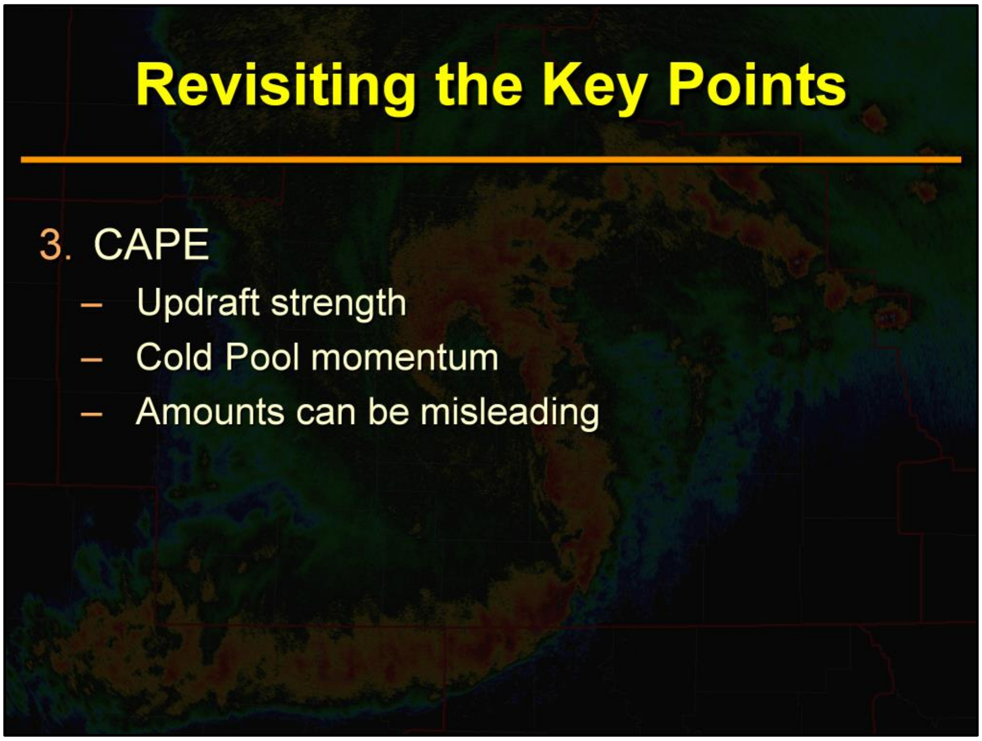
The mesoscale analysis page from the Storm Prediction Center can be found at the URL shown above, and has been developed to aid forecasters assess the severe threats evolving over the next 0-3 hrs. The SPC runs a 2-pass Barnes surface objective analysis around 5 min after each hour, using the latest RUC forecast as a first guess. Next, the surface data is merged with the latest RUC forecast upper-air data to represent a 3-dimensional current objective analysis. Finally, each grid point is post-processed with a sounding analysis routine called NSHARP to calculate many technical fields related to severe storms.

The parameters are organized under their primary uses on the left hand of the page under the yellow headers. In the case displayed here, the ‘Composite indices’ sub-menu is expanded to display the available fields. A description of each field is available near the top center of each page for each of the parameters.



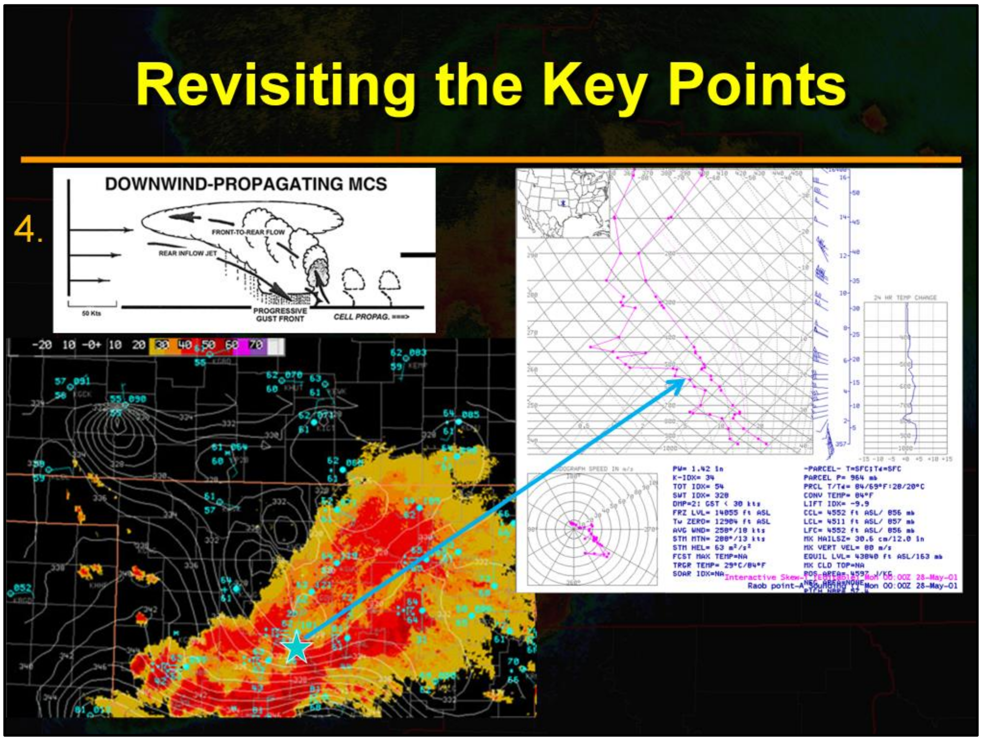
To revisit some of the key points made in the lesson: QLCS events can be described as intense, multi-hazard events that are based on many conceptual models with recognizable features such as rear-inflow jets, bow echoes, linear MCSs, and derecho producing windstorms. The recognition of these features are typically made by evaluating the following parameters , which have been shown to play important roles in helping determine severity and duration:

1. Forcing - look for deep layer shear that’s mostly boundary-parallel,
2. Shear - longer straighter hodographs favor the QLCS derecho producing windstorm types, but, the pattern can be similar to supercells. You need to carefully consider the nature of the convective initiation and the storm motion relative to the forcing to help evaluate the role of this factor for each event.

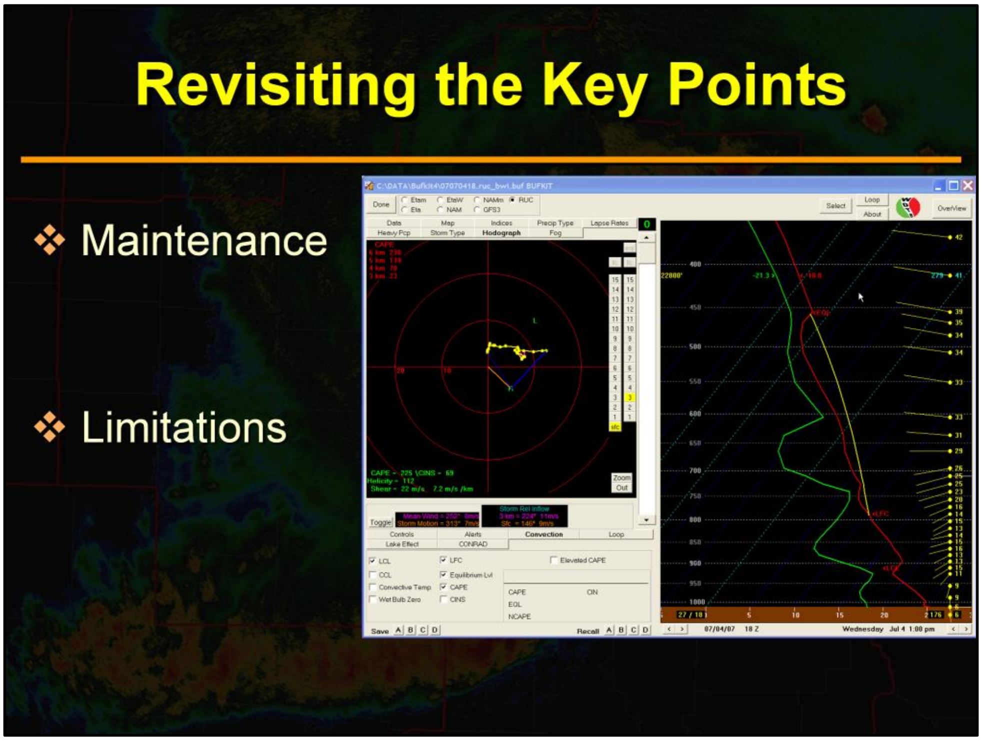


Key Point 3) CAPE- A multifaceted, necessary parameter related to strength of updrafts along the leading edge of the cold pool and strength of subsequent downdrafts. CAPE helps quantify intensity of updraft, and how the system is provided a supply of moisture and energy .

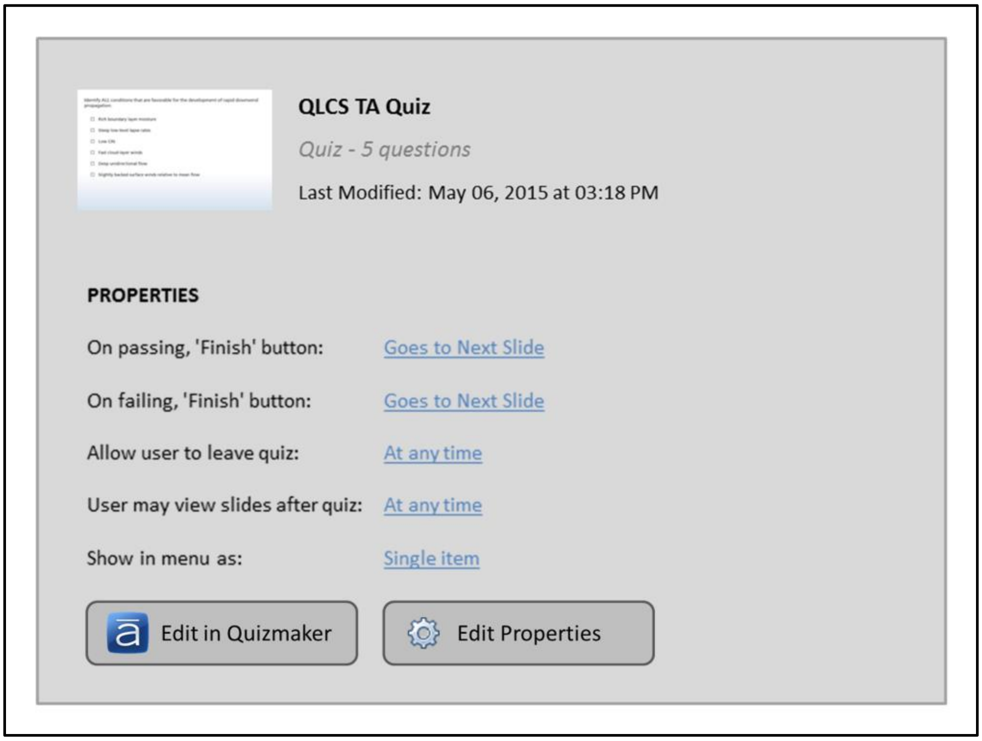
Note that computed amounts of CAPE can be misleading when trying to use this variable as a discrimination variable for convective mode.



And finally, the 4th Key point: Downwind propagating MCS. Remember that the development of rapid, downwind cell propagation is tantamount to estimating QLCS intensity. Factors such as rich, boundary-level moisture, steep, low-level lapse rates, minimal CIN, fast, cloud-layer flow, deep, unidirectional flow, and slightly backed near-surface winds relative to the mean flow are ALL factors that favor the development of this situation. The example shown is from forward propagating MCS from May 28, 2001 in Oklahoma.



Finally, the SPC has several parameters to help you discriminate if QLCS –type of events are the most intense and long-lasting. You should use these to help assess threats associated with QLCS events. And remember, there are limitations in our science of forecasting convective mode and eventual evolution, as well as determining specific threats due the fact that these parameters don't always tell the full story. Use of the SPC Mesoanalysis Page (http://www.spc.noaa.gov/exper/mesoanalysis/) as well as Model Forecast Sounding applications like BUFKIT are some of our best forecasting tools to assess subtle changes in the mesoscale environment which can influence modality changes.



This is a quiz to check your learning.

Contact Information

- nws.wdtb.awocsevere-list@noaa.gov
  - Questions on any AWOC Severe lesson
- bradford.n.grant@noaa.gov
  - 405-325-2997
  - Questions on this lesson